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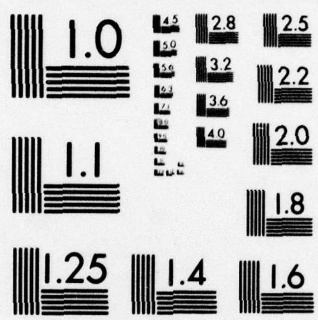
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FOREIGN TECHNOLOGY DIVISION

AIR FORCE SYSTEMS COMMAND

PRESENT STATE AND THE PREDICTED DEVELOPMENT
DIRECTION OF DIGITAL SIGNAL TRANSMISSION SYSTEMS

by

E. Juszkiewicz, M. Baraniecki

FOREIGN TECHNOLOGY DIVISION

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Present State and the Predicted Development Direction of

Digital Signal Transmission Systems

by

Edward Juszkiewicz and Marian Baraniecki

In the last few years we have observed growing interest in digital systems, especially PCM. This is caused mainly by the possibility of multiple utilization of city cables, low cost of multiplexing and direct switching of PCM signals in telephone switching centers. Rapid development of PCM systems caused a situation in which there exists the whole family of systems with differing parameters, such as multiplicity, linear throughput and others. Newer PCM systems with higher and higher multiplicity are developed and will constitute the next steps in development hierarchy of PCM systems. Certain proposals exist which recommend the creation of PCM systems hierarchy in relation to the analog systems, so that one could utilize PCM links for transmission of FDM groups. While creating new PCM systems one did not forget the cooperation with data transmission and telegraphy. Number of channels was reserved for these applications, and in the specific case -- after a certain adaptation -- the PCM 30/32 system was adapted for data transmission only.

For integrated digital networks the development of PCM systems in coordination with data transmission, telegraphy and other systems, is very urgent. According to this concept, the signals originating from the above mentioned sources, would be switched in the electronic switching center, with a certain fixed rate. It is essential, that the digital signals formed by digital multiplexing of PCM groups or the direct coding of certain number of telephone or other wide band signals (videophone, radio, television, FDM groups), be identical. This would allow switching of above signals and transmission over the

single ~~line~~ transmission link.

The main problem is, that different countries adopted and developed different PCM systems, differing in throughput, frame structure and signaling frame, organization of the entire system, parameters of transmission links, etc. The important factor is also the choice of digital multiplexing method: bit division or time division.

It was accepted that the mandatory method in interfacing of different systems with the electronic switching center, in context of integrated network, will be the bit word division method, or ~~differently speaking~~, time slice division. In USA, England and Japan the PCM 24 systems were built with throughput of 1.544 Mbits/s, while in France, West Germany, Italy the PCM 30/32 systems exist, with throughput of 2.048 Mbits/s, and differing frame structure, synchronization and signalization method. Similar situation exists in II level systems. USA and Canada adopted a system with throughput of 6.312 Mbits/s. England, Belgium - the 6.336 Mbits/s system, and the Socialist countries, France, Italy, West Germany and Holland selected the 8.448 Mbits/s system, (they developed it or are presently developing it.)

Poland adapted the 8.448 Mbits/s throughput, and on the basis will develop the integrated digital network concept. In first stage, it is expected that the introduction of different information signals to the network will be asynchronous. In the future the integrated network will be synchronous.

Present State of Digital Teletransmission Systems

Pulse-code modulation system PCM 30/32.

According to CCITT and Permanent Commission on Radio and Electronic Industries of Comecon recommendations, the presently recognized basic

pulse-coded modulation system is PCM 30/32. This system is capable of working in non-Pupin and nonsymmetric voice-grade or radio lines, or could be used as a basis for further multiplexing. PCM 30/32 is expected to work with digital electronic switching centers. The CCITT recommendations are finalized for the PCM 120 system, into which are multiplexed four 30 channels groups, originated from the PCM 30/32 system. The PCM 30/32 system gives the most economical development possibilities for local and regional networks. It can be used in very wide range for data transmission, due to its principle and time structure.

The PCM 30/32 system is intended for service in city and regional networks for distances from a few to few tens of kilometers. The system can be installed on balanced line cables, with channels insulation made of paper-air, styroflex-air or plastic type, and copper conductors with 0.5 to 1.4 mm dia., or equivalent diameter aluminum conductors. The linear transmission channel is realized on two balanced pairs, separate for each direction of transmission, using repeaters distributed along the line in cable wells or other assigned locations. In the case of radio transmission, the cable link is replaced by a radio link. Transmission on the radio link takes place on two channels and in each channel the signals are transmitted on different carrier frequencies. Bewteen two terminals of linear channels, 25 repeaters may be inserted without the need of a jitter damper.

The PCM 30/32 system provides the possibility of half or full duplex connection with the switching center, that is, it assures the transmission of required criterion and alarm signals necessary for interaction with the exchange. The parameters of PCM 30/32 system are:

- telephone channels - 30
- time slices in frame - 32

- frame duration - 125μs,
- frames in multiframe - 16,
- sampling frequency in channel - 8 kHz $\pm$ 0.4 Hz,
- peak to peak quantization levels - 256,
- bits in channel's time slice - 8,
- signaling channels for each telephone channel - 2,
- normal time duration for signaling frame - 2 msec,
- nominal binary throughput of linear signal - 2.048 Mbits/s,
- logarithmic compression characteristics A = 87.6 approximated by 13 segments, in which the neighboring segments have slopes in ratio 1:2,
- impedance 600Ω- symmetric.

For a transmission in acoustic channels a linear bipolar signal was used, with HDB3 code and pulse amplitude of 3V $\pm$ 10% and 244 nsec duration. The characteristics of the dependence between the signal-to-quantization noise ratio and the signal level, while testing with white noise in the range from -3 dBm0 to -55dBm0 should not deviate more than 4.5 dB from the theoretical characteristics obtained from calculations.

Criteria of frame phasing loss and recovery are as follows. The frame phasing loss is detected if the errors are found in three consecutive frame phasing patterns. The frame phasing should be considered recovered if one can detect:

- presence of the correct frame phasing pattern (zero frame),
- lack of the frame phasing pattern in the following frame (first frame),
- presence of the correct frame phasing pattern in the following frame (second frame).

The frame structure is as follows:

- sequence number of time slices SC0, SC1, SC2, ... SC31;
- sequence number of telephone channels KT1, KT2, . . . KT15, KT17, KTL', . . . KT 31;
- sequence number of frames in the signaling frame R0, R1, . . R15;
- frame phasing pattern is located in frames R0, R2, R4, . . . R16 and has the form X0011011;
- subpattern is located in frames R1, R3, R5, . . . R15 and has the form X1XXXXXX, where X is an arbitrary bit;
- the signaling channels are located in every SC16 slice of R1 through R 15 frames;
- signaling channels intended for telephone channels:

K1 in R1	B1 through B4
K2 in R2	B1 through B4
K 15 in R 15	B1 through B4
K 17 in R1	B5 through B8
K 18 in R2	B5 through B8
K 31 in R 15	B5 through B8

The existing PCM 30/32 systems in the world enable the transmission of data, telegraphy and radio programs in time slices normally occupied by telephone. The empty spaces in a frame, while utilizing full 30 telephone channels, may be used only for slow telegraphy and data transmission, that is, 30 - 500 baud channels. Each telephone channel used for data transmission allows the 64 Kbits/s data transmission rate.

A synchronous system of secondary digital multiplexing with 8.448 Mbits/s throughput with positive filling.

Presently, the agreement was reached, in both forms CCITT and Comecon, about the requirements for the secondary digital multiplexing system with

8.448 Mbits/sec throughput and with positive filling. This is an asynchronous system, and allows the multiplexing of four bit streams originating independently in four PCM 30/32 systems, and creating the possibility of having 120 telephone channels. This system, which will be called PCM 120 in the remainder of this chapter, has a frame structure shown in Table 1. It is expected to work in non- Pupin symmetric lines, where the analog systems are working presently. In some countries, special symmetric cables are manufactured for digital transmission with 8Mbits/sec throughput, or microcoaxial cables for digital transmission, which also can be used for digital transmission with high order multiplexing. The distance between repeaters for PCM 120 system is about 4 km. In order to extract from the 8Mbits/sec digital stream, the bits corresponding to each primary ~~stream~~ stream (PCM 30/32) and to eliminate filling bits, the additional bits are added to the 8Mbits/sec stream, which form the frame and filling control signal. The filling control signal consists of three bits distributed in the second, third and fourth subgroup. The presence of filling is detected after the receipt of 111 signal, and its lack, after receipt of 000 signal, with a majority of bits deciding.

Bits from the primary PCM 30/32 streams are interleaved. The system is synchronized with a 8448000 Hz clock with $\pm$ 30 $\times 10^{-6}$ tolerance. The primary streams are received with the 2048000 Hz throughput with $\pm 50 \times 10^{-6}$ tolerance. The loss of frame phasing is detected, when the errors are found in four consecutive frame phasing patterns. The frame phasing recovery should be confirmed, if the correct frame phasing pattern is detected in three consecutive frames. The 12th bit is reserved for signaling in international exchange. In domestic exchanges, if it is not used, has a constant zero value. The 11th bit is used to transmit between terminal stations, information on other terminal malfunctions. Presently, many firms, mainly European, manufacture or are about to

manufacture the PCM 120 system devices. The system with positive filling doesn't allow alternate synchronous and asynchronous work, so most likely, worldwide research will be conducted in the direction of developing the universal system with positive-negative filling, allowing both synchronous and asynchronous operation. The proposal for such a system was made by the Soviet Administration, which proposed a system with positive-negative filling and two-command control.

Development Direction of Higher Order PCM Systems

The III and IV Order Systems

The only existing CCITT recommendations are for I order system with 2.048 Mbits/sec throughput, and II order system with 8.448 Mbits/s throughput. However, in some European (and not only European) countries, without waiting for the official recommendation of the international organization, the systems of very high multiplexing and throughput were developed.

Using the previous hierarchy of PCM systems as a model, some logically assumed, that the next development step should be the system multiplexing 4 secondary systems, and with the 8.448 Mbits/sec throughput. They accepted the transmission throughput equal to 34.368 Mbits/sec. Among others, the Italian Administration supported this system and at the beginning of 1974, sent to CCITT a proper document, proposing the higher order hierarcy of PCM systems, basing it on the II order system as the starting one.

Some other countries, however, among others France, are sceptical about the 34 Mbits/sec system proposal and doubt about the very concept of this system. They consider as proper to pass directly from secondary 8.448 Mbits/sec system to 139.264 Mbits/sec system, with elimination of all other possibilities. France is developing , its own system with

throughput of52 Mbits/sec 6 x 8.5 MHz, but exclusively for domestic use, similarly ~~as~~ it has an already existing 26 Mbits/sec system. Both systems work on the radio lines.

As the result of a controversy, CCITT appealed to the administration of all countries belonging to this organization, that they take a stand whether 34.368 Mbits/sec system should be developed, or if it should be abandoned and ~~to~~ one should go directly from the 8.448 Mbits/sec system to the IV order 139.264 Mbits/sec system. As far as the IVth order system is concerned, the majority of Administrations **endorsed** its usefulness and necessity of development in PCM systems hierarcy.

The Italian Administration proposed also its own ~~proposal~~ design of this system, which is presented at the end of this chapter. The linear signal is transmitted on coaxial lines with the dimensions 0.65 x 2.8 mm; repeaters are placed every 2 km.

The frame structure of III order system is shown in Table 2, and of the IV order system in Table 3.

<u>II order system with 8.448 Mbits/sec throughput and positive-negative filling and two-command control.</u>

There is no appropriate CCITT recommendations for this system. Therefore, the Soviet proposal is presented in four paragraphs:

- secondary group with 8.448 Mbits/sec consists of 4 primary groups with 2.048 Mbits/sec. throughput; in multiplexing, bit interleaving was used and positive-negative filling;
- service bits in digital stream are formed in 8 bit groups, which separate the consecutive frames; although such service bit grouping causes the increase of required memory capacity, it considerably improves the time frame phasing recovery, each frame of multiplexed signal contains 64 information bits from each primary system, so it consists of 256 information bits and 8 service bits;

- maximum deviation of nominal 6.446 Mbits/sec throughput is 200 bits per million;
- multiplexing device must contain one or several low-frequency binary channels; each such channel is used for service communication and for line and terminal device control.

The main advantage of asynchronous system with positive-negative filling is the possibility of synchronous ~~work~~ operation - in contrast to the secondary multiplexing system with positive filling, where certain initial frequency difference fk - fs is required between channel throughput and input signal throughput. The existence of this difference makes it possible for use in synchronous operation.

The Presently used system for control and steering of filling process, is quite complicated, which contributes to higher costs and manufacturing difficulties, and so the Soviet side proposed the use of positive-negative filling with two-command control. This improvement will not change the general characteristics of positive-negative filling, assures the easy change from the asynchronous to synchronous mode and greatly simplifies the generation of commands and receiving systems.

The main disadvantage of "classical" positive-negative method is the necessity of transmission of three command types, which greatly complicates the receiver and transmitter steering.

The increase or decrease of throughput by a single time interval, which is usually equal to the time slice, is accompanied by a transmission of one or two commands, called active. The third command, which corresponds to no change in information throughput, is neutral. The following progression of reverse commands is comparable for the transmission of neutral commands, not influencing the change in information throughput. It is possible, therefore, to pair the reverse active commands in order to neutralize them. Because of that, one was able to obtain the control of

positive-negative filling with two commands. The principle of steering with two commands is shown in Fig. 1.

Additional fluctuations of output signal, observed in this case, occur with a frequency equal to frequency of command repetition. This is sufficiently large frequency and may be easily damped with a filter extracting the information from input signal. In this case, similar to the classical three command filling control, the jitter value, originating from the waiting time, is close to zero, and the low-frequency amplitude fluctuations created by an initial fk - fs difference,is equal to the time slice width. It is recommended that the value of the ratio fo/ (f_k -fs) max be large, where fo is the command frequency. The jitter amplitude is:

$$A \approx \frac{3\,(f_k - f_s)_{max}}{f_o} \cdot \frac{1}{f_s}$$

Because of the fact that fo is selected to be 10 to 20 times larger than the maximum allowed difference (fk -fs), the phase fluctuation amplitude cannot be reduced more than by 20 to 25% of the time slice width.

In using the two-command steering of the positve-negative filling process, by repalcing the neutral commands by pairs of reverse active commands, the jitter is considerably reduced, which is the advantage of "pure" positive filling, but at the same time one preserves all the advantages of positive-negative filling and especially its main advantage - the possibility of synchronous operation with the primary groups.

Synchronous II Order System

The principle of this system is the synchronous multiplexing of four 30 channel primary groups, with 2.~~048~~ 084 Mbits/sec throughput, into one

secondary group. The characteristics of this system is the single source timing of secondary group throughput. The timing signals for the 2.048 Mbits/sec primary groups are taken from this timing source.

The throughput of the secondary group in this system is f = 8.448 Kbits/sec and is related to the throughput of primary groups by a formula:

$$f_z = 4 f_1 \,(1-r) \text{ kbits/sec}$$

where $r = 1/32$ is the secondary group oversize.

The synchronous system frame consists of 528 bits divided into two subgroups with 264 bits each. At the beginning of each subgroup there are 8 bits, which are used to transmit the frame phasing pattern, data on the system and signaling and also synchronization of the signaling frame.

Steering from a single timing source takes place as follows: in multiplexing station A there exists a main timing signal source, GSC - a crystal-controlled oscillator with frequency of 8.448 MHz. The secondary group signal is sent from station A to station B with 8.448 Mbits/sec throughput. There, the timing signal for the receiving and transmitting section is extended. In the receiving section of station A, the timing signal is extended from bits that arrive from station B transmitter, and at the same time the information from the four primary groups are extracted and read by the timing signal. The system consists of two multiplexing stations and a link with repeaters every 4 km.

The receiving station consists of four 2 Mbits/sec receiving sections, each containing a regenerator and fixed size memory system. The necessity of using the buffer memory is caused by signal phase fluctuations (so called jitter). The phase shifts are caused by transit time changes, which are caused by cable temperature changes. These are the seasonal changes for underground cables and daily changes for overhead cables. To calculate

the size of this memory, a typical line was considered, built from micro coaxial cable with dimensions 0.65 x 2.8 mm, and having connections every 30 km for a primary group, and 100 Km for a secondary group.

Assuming that the temperature coefficient of electric permeability is 6 x 10^{-6}/ °C and the average transit time through the transmission medium is 5 μsec/km, one can calculate the maximum change in signal transit time through the line, using the formula:

$$\Delta\Theta = 3 \cdot 10^{-3} \cdot L \cdot \Delta T \ [\mu s]$$

where: $\Delta\Theta$ - change in transit time; L - line length in km; ΔT - temperature change in °C.

With the average daily temperature change equal $\Delta T = 10°C$, the value $\Delta\Theta$ = 3.9 μsec. Knowing then, that the length of a single bit in the primary group is 0.488 μsec, one can calculate the memory size, which must be used: 3.9 : 0.488 = 8 bits. With a smaller memory, the shifts of frame phase (slips) will occur too often. As one can see, the line length in the synchronous system is limited by a change of primary group digital signal transit time. An additional difficulty is the rigidity and limited application in networks, because of limited line length.

The above disadvantages may be countered by a number of advantages of synchronous multiplexing, such as: good economy, simplicity of operation, and possibility of creating so called "synchronous zones" in defined areas of telephone network. Interface between such "zones" could work asynchronously. An example of synchronous system line is shown in Fig. 2.

Studies on Optimal Frame Structure

In many parts of the world studies are being made on a frame structure which could be universal for all applications of integral

network[5]. Due to the development of solid state technology and possibility of manufacturing the integrated logic systems with higher and higher speeds, one is able to use for the information exchange in integrated network speeds higher than 2.048 Mbits/sec, that is 8.448 Mbits/sec. Some Administrations set forth their own proposals for the frame structure for different applications in the network. The Italian Administration proposed three versions of frame structure for different applications:

1) for digital communication between two digital electronic exchanges,
2) for digital communication between digital electronic exchange and PCM multiplexing centers of II order,
3) for digital communication between digital electronic and synchronous multiplexing centers of II order.

The block diagram of the network which contains all three above mentioned possibilities, is shown in Fig. 3. According to the Italian Administration, the third case is least useful of three mentioned. Presently, such synchronous multiplexing centers, are not taken into account. The throughput of digital connections should be 8.448 Mbits/sec, which corresponds to 132 time slices. The center's clocks operate at the frequency of 8.192 MHz (4 x 2.048 Mbits/sec) and thus the switching system may use at most 128 time slices. This is why the additional device is required producing four additional time slices in addition to 128.

The Italian Administration is of the opinion, that the additional time slices should be distributed uniformly in a frame. This solution causes a small jitter at the clock conversion from 8448 ----- 8192 and requires small buffer memory. In all anticipated applications two or four additional time slices are used for frame phasing and service, and the

remaining two slices for other uses.

The frame phasing pattern should completely occupy the zeroth time slice. The proposed pattern has the form 10111000. The first five bits of the time slice no. 66 should contain the complement of the phasing pattern (that is, 01000l), and the remaining two bits of 66th time slice should be used to provide service information (that is, frame phasing loss or lack of pulses entering the link and terminals). Taking into account the remaining 128 bits, the following structure is proposed:

1) between digital electronic exchanges - 127 time slices for telephony or signaling channels 64 Kbits/sec and one time slice no. 1 reserved for domestic use;

2) between digital electronic exchange and PCM devices - 120 time slices for telephony, 4 slices for signaling and 4 service time slices.

In the structure 1 the time slice reserved for domestic use is assigned for the internal service in digital electronic exchanges. In the structure 2 the low transmission efficiency is justified, that is the 64 kbits/sec signaling channels are the same as used in 2.048 Mbits/sec system. This comes about from lesser complexity in the digital electronic exchange. The structure 2 can be used also in the case, where 4 free time slices are used for the transmission of frame phasing signals in primary group. The frame structure, which is the subject of Italian Administration proposal, is shown in Fig. 4.

The Dutch Administration also presented its own proposal concerning the frame structure for the same three cases, which were the subject of Italian Administration studies, and the Dutch Administration is of the opinion that the third of the considered cases will have the greatest use in the integrated network.

The general charecteristics of the system proposed by the Dutch

Administration : nominal throughput of 8.448Mbits/sec, from which the 132 time slices of 125μ sec (1056 bits) are derived; allowed tolerance of bit throughput depends on type of application; the time slice interleaving is used (not bits).

If the common signaling channel is used for communication between digital electronic exchanges, it is necessary to assign separate time slices for signalization. Use of digital electronic exchange may require the choice of certain proper time slices for speech and common signaling channel. It is assumed, that in the case of using 8.448Mbits/sec throughput, the time slices above 128 (that is, slices 0, 1, 66 and 67) will be extracted from the bit stream of 8.448 Mbits/sec throughput before switching, thus it follows, that the exchange clock should have a frequency 8.192 MHz.

Table 4 shows the channel assignment with respect to application in the described possibilities, and the Table 5 shows the time slice distribution of these same possibilities. Table 6 gives the structure of the signaling frame. The signaling frame consists of 16 frames, which follows from 500 Hz signaling speed (with maximum signal distortion of 2 msec) and their capacity of 4 bits per channel. The frame structure is shown on Fig.5. Dutch Administration proposes, that the frame phase loss signaling take place only after incorrect receipt of four consecutive frame phasing patterns, and the decision on frame phasing recovery follow the correct receipt of three consecutive frame phasing patterns. It is considered necessary and economically justified, that in addition to an internal, main timing generator every station have an input for the external timing signal connection. The Italian and Dutch Administration proposals are very similar and after proper consultations with other Administrations, the compromised frame structure based upon

Italian and Dutch proposals, may be approved by CCITT for development in all countries.

Interface of Digital Systems Anticipated for the Integrated Network With the Systems Presently in Use

Transmission of frequency multiplexed channel groups (FDM) through the digital lines is an uneconomic means of telephone channel transmission. For example, the transmission of 12-channel primary FDM group requires link of 2.048 Mbits/sec throughput, which has the ability of 30 channel transmission in PCM 30/32 system. In order to use the same link as in PCM 30/32 system, the transmission of the primary FDM group will require the normal primary group equipment and the special analog-to-digital converter. As one can see, this solution is more expensive than the PCM 30/32 system. In the digital network, however, situations may exist, where FDM group transmission in digital form can be economically justified. An example of this, there can be the situation, when the cable normally used for analog transmission is used for digital transmission. Due to the interferences, which cross over from the digital systems to analog systems, the FDM group should be transformed to digital form. Transforming the FDM groups to acoustic channels level, and then multiplexing them in the PCM technique, is a less economical solution than the transmission of the entire group in digital form.

In the selection of sampling frequency, one has to pay attention to FDM group band location. If the ratio of limiting frequencies does not exceed 2, then the sampling frequency can be only little higher than the upper band frequency. At the same time the condition must be satisfied, that in the sampling process, the side bands of the PAM signal do not overlap. As an example, the sampling frequency of the FDM primary

group in the 60 - 108 kHz band can be within the 108 -120 kHz limits.

The digital signal throughput is affected both by sampling frequency and number of bits in the code word, therefore, while choosing the sampling frequency, one has to take into account the throughput of PCM link, through which the PCM signals will be transmitted.

The Device for coding and decoding the primary FDM groups (in abbreviation codec PCM -FDM12) may independently interface with the PCM 30/32 system link, or with the PCM link through a digital multiplexing device. Codec PCM-FDM12 contains double-ended analog input and output, number of code elements 11 - 12, linear coding type and double-ended digital input and output. Device for coding and decoding secondary FDM groups (Codec PCM - FDM60) is intended for coding and decoding 60-channel secondary groups which are frequency multiplexed. The most economical solution of Codec PCM - FDM60 is a translation of the 312 - 552 kHz band to the 12 - 252 kHz band. In this case the sampling frequency must be at least twice as large as the highest band frequency; that is, larger than 504 kHz. In practice it is written 510 - 530 kHz. Such a sampling frequency allows to obtain on the Codec output 6.144 Mbits/sec throughput, or three parallel digital signals with 2.048 Mbits/sec throughput. The codec with 3 x 2.048 Mbits/sec outputs has the advantage, that after adding one more primary PCM 30/32 group, it can directly interface to the digital multiplexing device. In addition, this solution allows the transmission of 60-channel secondary group through low frequency cables, which in normal situations are not suitable for the frequency systems. Codec PCM - FDM60 has double-ended analog input and output digital 3 x 2 - end input and output, linear coding, number of code elements=10 - 11.

Use of FDM group coding and decoding devices will be the transitional solution while introducing the integrated network. When the completely integrated network exists, and the analog systems will not be used, and the described devices will not be necessary.

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Table 1. Frame Structure in PCM 120 System

Subgroup Number	Type of bits	Bit number
I	Frame phasing signal (111010000)	1 - 10
	First free bit (for domestic use)	11
	Second free bit (for international use)	12
	Information bits	13 - 212
II	Filling control bits for:	
	Channel I	1
	Channel II	2
	Channel III	3
	Channel IV	4
	Information bits	5 - 212
III	Filling control bits	1 - 4
	Information bits	5 - 212
IV	Filling control bits	1 - 4
	Information filling bits for:	
	Channel I	5
	Channel 2	6
	Channel 3	7
	Channel 4	8
	Information bits	9 - 212
Frame length		848 bits

Table 2. Frame Structure of a 34.368 Mbits/sec I20 $\times 10^{-6}$ throughput system

Frame structure	Bits Location
Subgroup I	
Frame phasing pattern	1 - 10
Free bits	11 and 12
Information bits	13 - 384
Subgroup II	
Bits C_{j1}* of filling control	1 - 4
Information bits	5 - 384
Subgroup III	
Bits C_{j2}* of filling control	1 - 4
Information bits	5 - 384
Subgroup IV	
Bits C_{j3}* of filling control	1 - 4
Filling bits	5 - 8
Information bits	9 - 384
Number of secondary groups	4
Binary throughput of secondary groups	8448 kbits/sec
Frame length	1536 bits
Maximum filling coefficient of single secondary group	22.375 kbits/sec

*) Symbol C_{ji} denotes i-th filling control bit, originating from j-th secondary group

Table 3. Frame structure of 139264 kbits/sec $\pm$ 20 $\times 10^{-6}$ system

Frame structure	Bit location
Subgroup I	
Frame phasing pattern	1 - 12
Free bits	13 - 16
Information bits	17 - 488
Subgroup II, III, IV, V	
Bits C_{ji}*) of filling control, i = 1 - 4	1 - 4
Information bits	5 - 488
Subgroup IV	
Bits C_{ji}*) of filling control	1 - 4
Filling bits	5 - 8
Information bits	9 - 488
Frame length	2928 bits
Number of information bits assigned to each tertiary group	723
Maximum filling coefficient for each tertiary group	47.56 kbits/sec
Binary throughput of each input tertiary group	34368 kbits/sec
Number of tertiary groups	4

*) symbol C_{ji} denotes i - th filling control bit originating from j - th tertiary group.

Table 4. Channel distribution according to application

Option	Telephony	Signalization	Primary Group frame phasing	Secondary Group frame phasing	Service
1	128	---	---	2	2
2	124	4	---	2	2
3	120	4	4	2	2

Table 5. Time slice distribution (SC)

Option	Time slice assignment	Time slice location
1	Frame phasing pattern	SC0 +Sc1 (bits 1-6)
	telephony	2 - 65
	service	66 and 67
	telephony	68 - 131
2	Frame phasing pattern	SC0 + SC 1 (bits 1-6)
	telephony	2 - 65
	service	66 - 67
	signalization	68 - 71
	telephony	72 - 131
3	Frame phasing pattern	SC0 + SC 1 (bits 1-6)
	Primary group frame phasing	2 - 5
	telephony	6 - 65
	service	66 - 67
	signalization	68 - 71
	telephony	72 - 131

Table 6. Structure of signaling frame

1. Frame number
2. Signaling frame phasing
3. Alarms
4. SC - time slice
5. KT - telephone channel

Nr ramki 1	SC 68		SC 69		SC 70		SC 71	
0	KT 1	KT 17	KT33	KT49	KT65	KT80	KT95	KT110
1	KT2	KT18	KT34	KT50	KT66	KT81	KT96	KT111
.								
.								
.								
14	KT15	KT31	KT47	KT63	KT79	KT94	KT109	KT124
15	KT16	KT32	KT48	KT64	fazowanie ramki sygnalizacyjnej 2		alarmy 3	

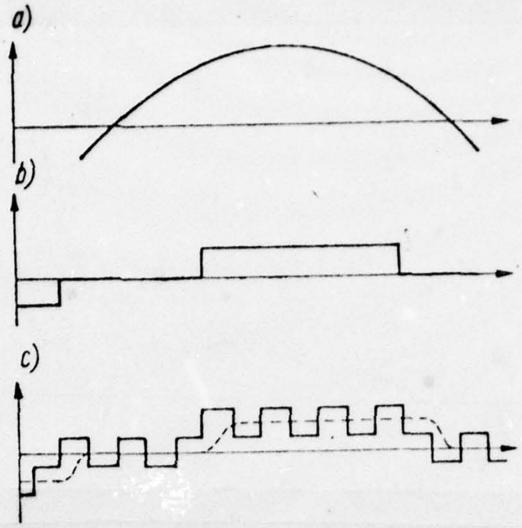

Fig. 1. Phase change with positive-negative filling a) input signal phase change, b) phase change with three command control, c) phase change with two command control.

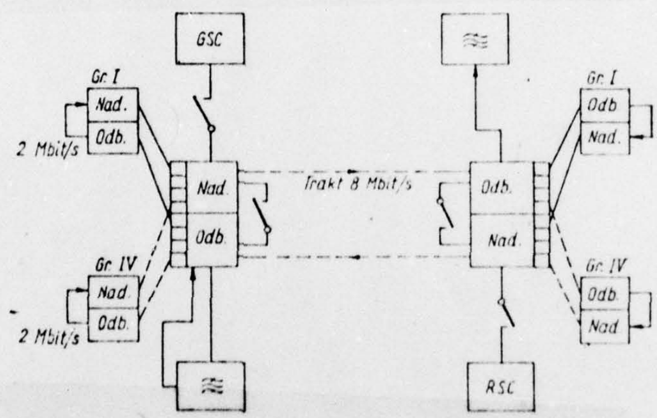

Fig.2. Synchronous system example

GSC - main timing signal

Nad - transmitter

Odb - receiver

25

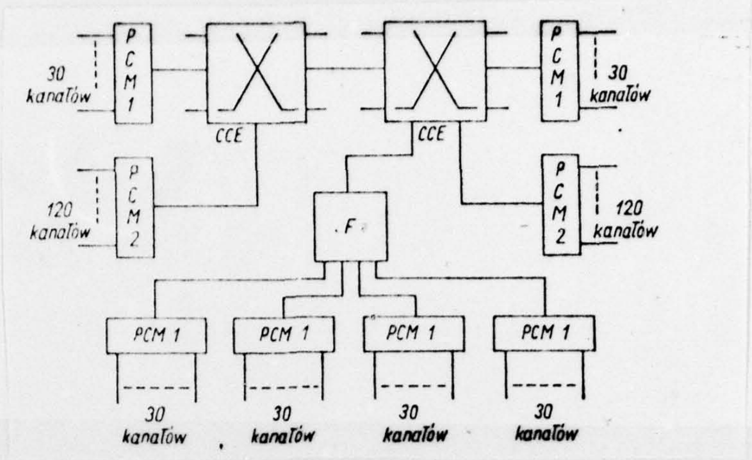

Fig.3. Digital network; CCE - digital electronic exchange, F - synchronous multiplexing device, PCM 1 - PCM 30/32 system device, PCM2 - PCM 120 system device, Kanałów - channels

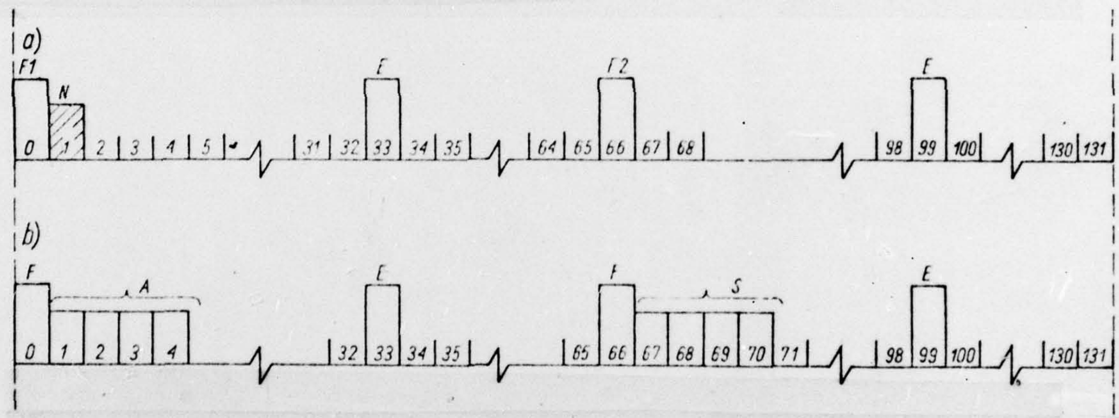

Fig.4. Proposed frame structure for 8.448 Mbits/sec

a) between two digital electronic exchanges

b) between electronic exchange and PCM devices, F1 - frame phasing pattern (1011100), F2 - frame phasing pattern complement (010001 - 2 Service bits), E - auxilliary time slices, N - domestic use bits, S - signalization time slices, A - auxiliary time slices.

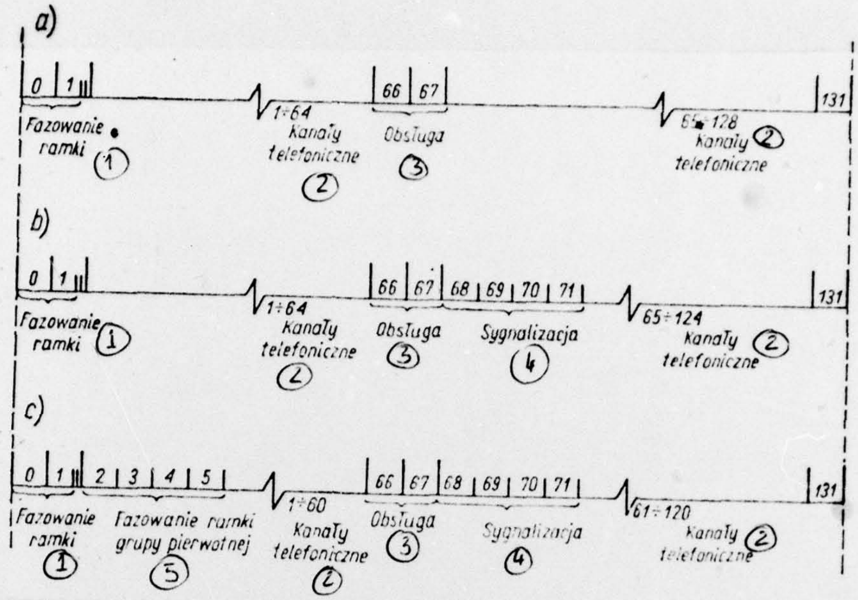

Fig.5. Frame structure according to Dutch Administration proposal: a) option1, b) option 2, c) option 3

1 - frame phasing

2 - telephone channels

3 - service

4 - signalization

5 - primary group frame phasing

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